CHEN E4231: Solar Fuels

***Note*:** this is an example syllabus that is reflective of typical content for this course. Specific subjects and assignments vary from year to year.

Lecture Hours: 3 pts

Prerequisites: Graduate standing or completed CHEN E4230. Open to grad and undergrads.

Time: Varies from year to year

Location: Varies from year to year

Instructor: Prof. Daniel Esposito

TA: Varies from year to year

Course Description. Fundamentals and applications of solar energy conversion, especially technologies for conversion of sunlight into storable chemical energy, or solar fuels. Topics include fundamentals of electrochemistry, photoelectrochemistry, kinetics of solar fuels production, solar harvesting technologies, and solar reactors for production of solar fuels. Applications include solar fuels technology for grid-scale energy storage, chemical industry, manufacturing, and environmental remediation. Additionally, students will learn to perform systems-level design and analyses of solar fuels technologies, with an emphasis on the integration of different solar harvesting and (electro)chemical unit operations. The course will include group projects based on a problem-based learning (PBL) philosophy that will (i.) expose students to interdisciplinary problems, (ii.) develop strong collaborative skills, and (iii.) promote critical thinking skills that are essential for solving open-ended problems.

Primary Course Objectives:
1. Learn fundamental principles that underlie solar and (photo)electrochemical energy conversion processes and technologies.
2. Develop problem-solving methodologies and creative thinking skills for the design and optimization of solar and electrochemical reactors.
3. Gain exposure to advanced topics in solar- and electrochemical engineering relevant to graduate-level research and emerging technologies in the clean-tech industry.

Required Text Book:

- PVCDROM, online photovoltaics textbook, Honsberg, C., Bowden, S., www.pveducation.org (Freely available)

Recommended Text Books:

1. West, Electrochemistry and Electrochemical Engineering, 1st Ed., 2012.

Other helpful references:

- PVCDROM, online photovoltaics textbook, Honsberg, C., Bowden, S., www.pveducation.org (Freely available)
- Principles of Solar Engineering, 3rd, Edition by D. Yogi Goswami, Frank Kreith, and Jan F. Kreider. Taylor & Francis, 2015.
- Handbook of Photovoltaic Science and Engineering Luque, A. and Hegedus, S., eds. 2011, 2nd ed., Wiley (Electronic version available for free through Columbia)
- J. Newman & K.E. Thomas-Alyea, Electrochemical Systems, 3rd Ed., Wiley, 2004.
- Bard and Faulkner, Electrochemical Methods, 2nd Ed., Wiley, 2001.
- M.A. Green, Solar Cells, Prentice-Hall, 1982.

Course Grades will be based on:
Homework and idea filter assignments (30%), Midterm (30%), Final Project (30%), Class participation (10%).

Exams: These dates are tentative and subject to change:
Midterm: TBD, Final Exam: TBD.
*If you require disability-related academic accommodations for exams, see the last page of this syllabus for more details about registering for Disability Services (DS).

Final Project: A group project will be assigned mid-way into the semester. This project is based on open-ended "solar fuels" problems that each group will get to choose from project ideas proposed by the class through an idea filter. A 4 page report and final presentation will be due by each group at the end of the semester (See course schedule next page).

Other Information:

- A few homework problems may require Matlab, Polymath, Python, or other comparable software to be used.
- Canvas will be used for course maintenance and information dissemination.
- Class participation may be based on attendance, active participation in discussions, Q&A, participation in Canvas discussion boards.

Homework Policy

- Homework is due at the ***beginning*** of class on the due date specified. No exceptions.
- Late homework will be accepted with a ***50% penalty*** up until the date the graded assignment is returned to the class or the hw solution has been posted online.
- Select homework problems will be graded.
- You must **show your work** in order to receive full credit. For problems solved using software such as Matlab or Python, include your code at the end of the hw set. If excel was used to generate solution plots, be sure to write-up all equations input into excel to generate those plots and fully describe the methodology used to solve the problem.
- **Collaboration** with classmates on homework is encouraged, with limits.
  - Acceptable collaboration includes discussing the problem statement, sharing ideas or approaches to solving the problem, and explaining concepts to one another.
  - You must write the name of collaborators on the top of your HW assignment.

- **Directly copying answers from ANY source is unacceptable.** Turning in anything that does not represent your own work and thought process is considered plagiarism and is subject to the Columbia Policy on Academic Integrity.
- For the report sections of the final project, plagiarism or "copying" of written sections is also strictly prohibited. Cite all references for information used within your report.
- **List your collaborators** at the top of your homework solutions when you turn it in.

Course Schedule: (Due dates and lecture schedule are subject to change)

Dates	Topics to be covered	Reading
Week 1	Course overview, intro to different types of fuels, intro to idea filters, efficiency definitions, intro to solar PV.	West Ch. 1, Ch. 2
Week 2	Electrochemistry intro, kinetics in electrochemical systems.	West Ch. 3
Week 3	Kinetics & thermo of electrochemical systems.	West Ch. 4
Week 4	Guest lectures on electroanalytical techniques and electrocatalysis in electrochemical systems.	
Week 5	Mass transfer in electrochemical systems, electrolysis devices, analysis of efficiency losses in electrolysis systems.	West Ch. 5
Week 6	Properties of sunlight, semiconductor physics.	PVCDROM Ch. 2
Week 7	Semiconductor physics, Basic phenomena in PV cells	PVCDROM Ch. 3.1, 3.2
Week 8	Basic phenomena in PV cells, p-n junctions & the ideal diode equation.	PVCDROM rest of Ch. 3 +Ch 4.1,4.2
Week 9:	PV cell structure, multi-junctions, PV in series/parallel, TEA.	PVCDROM Ch. 5
Week 10	University holiday (No class) **Midterm**	
Week 11:	tbd. (possible guest lecture or PV-electrolysis demo) PV-electrolysis systems (power matching, coupling losses)	Notes
Week 12	Hydrogen storage, using TMY data for system sizing. Photoelectrochemistry and applications.	Notes
Week 13	Photocatalysis and/or PV-electrolysis demo. **Slidecasts for final project due** Thanksgiving Day (no class)	Notes
Week 14	Possible guest lecture or demo **Turn in team report for final project** Likely date for team presentations	

Disability-related academic accommodations:

In order to receive disability-related academic accommodations for this course, students must first be registered with their school Disability Services (DS) office. Detailed information is available online for both the Columbia and Barnard registration processes. Refer to the appropriate website for information regarding deadlines, disability documentation requirements, and drop-in hours (Columbia)/intake session (Barnard).

Students registered with the Columbia DS office can refer to the Master TARF section of the DS Testing Accommodations page for more information regarding disability-related academic accommodations for this course.